Energy Harvesting from Infrastructure and Ocean Systems (EHIOS)

Proceedings

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Porous radiative cooling paint for building thermal management

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Porous Polymer Cooling Paint for Buildings

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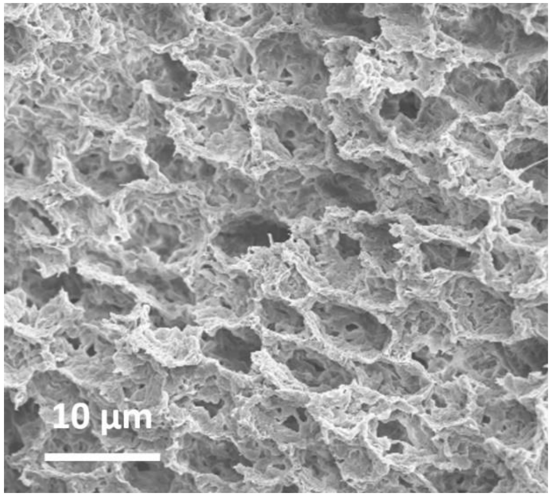
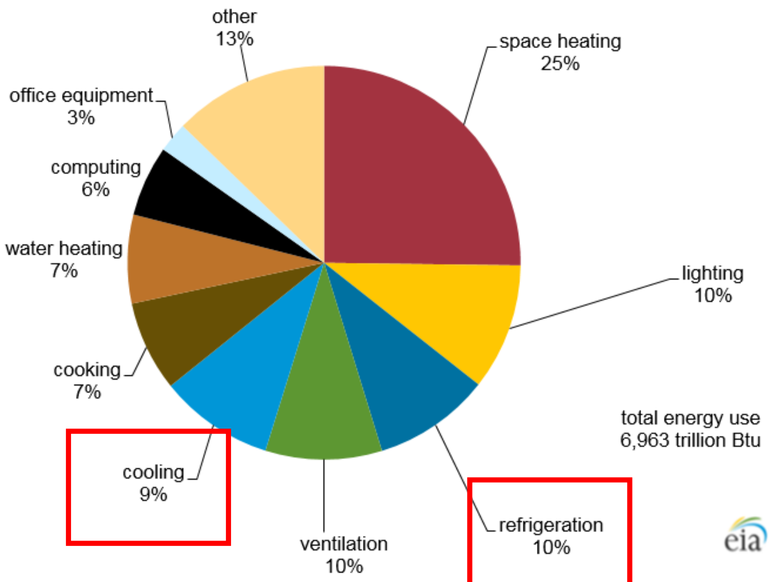
11-04-2019



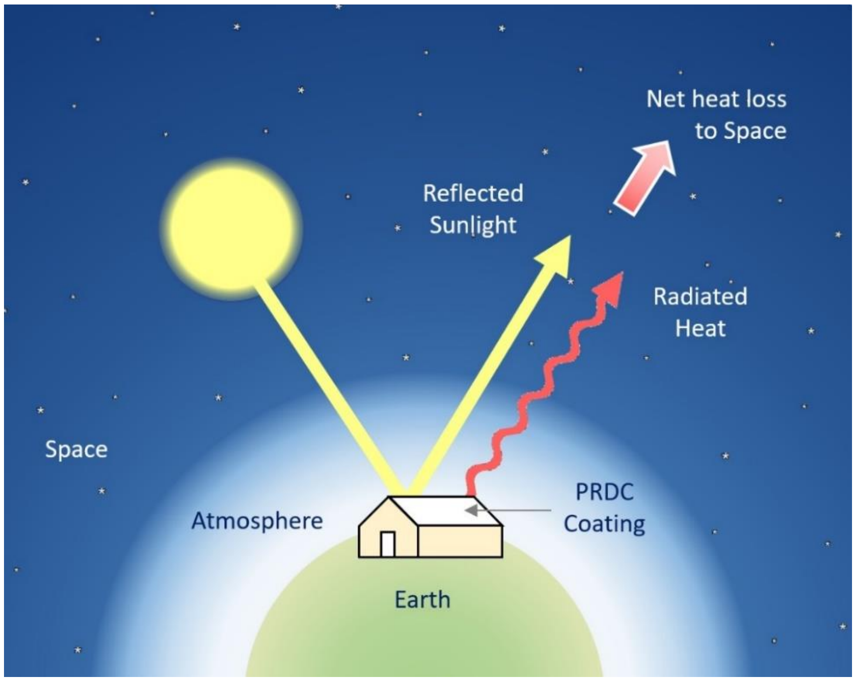
Thermal Management is Critical to Buildings

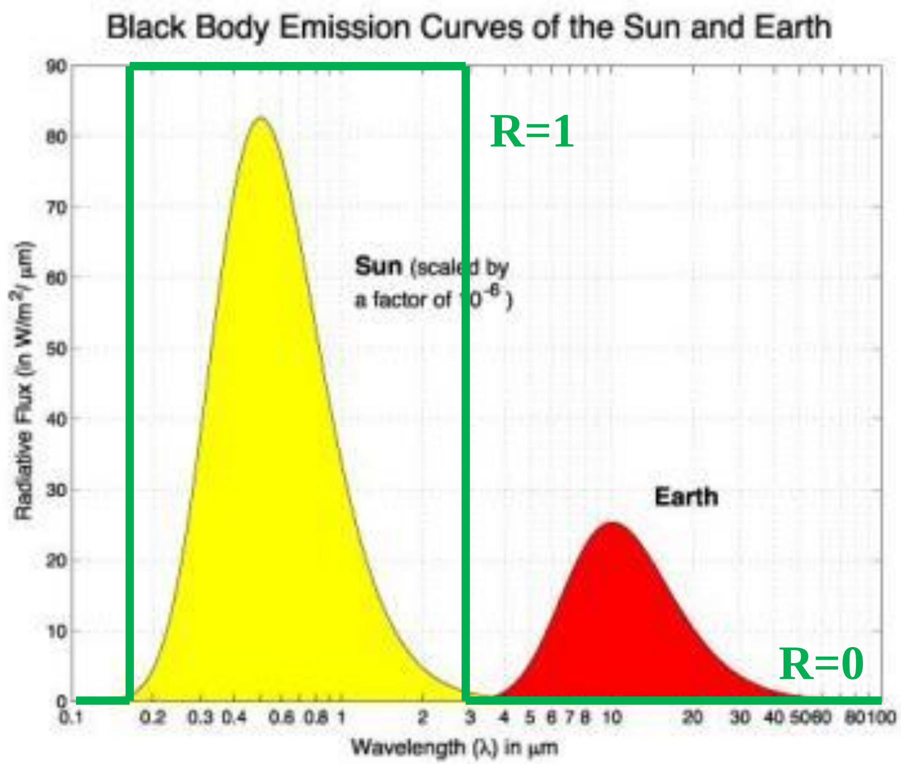


Source: U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey.

- Various scenarios need cooling (buildings, vehicles, shipping).
- Cooling/refrigeration counts for 20% of energy in buildings

Passive Daytime Radiative Cooling

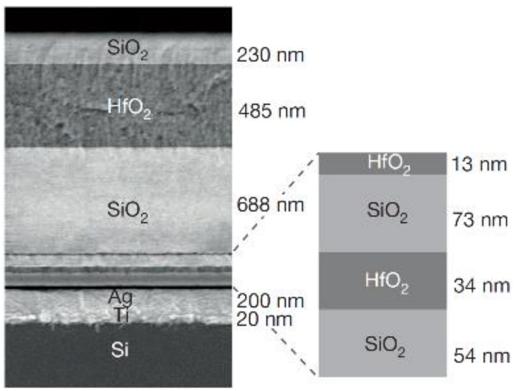


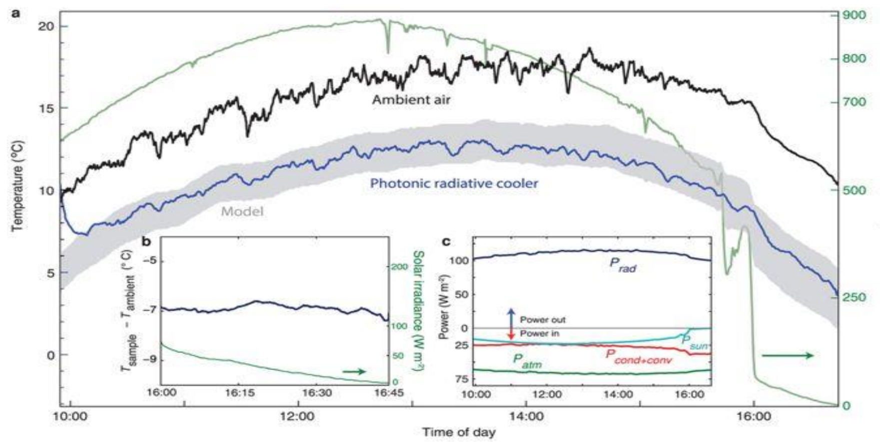


1-Reflctance (R) = Absorptance = Emissivity (ε)

Passive Daytime Radiative Cooling

Photonic crystal

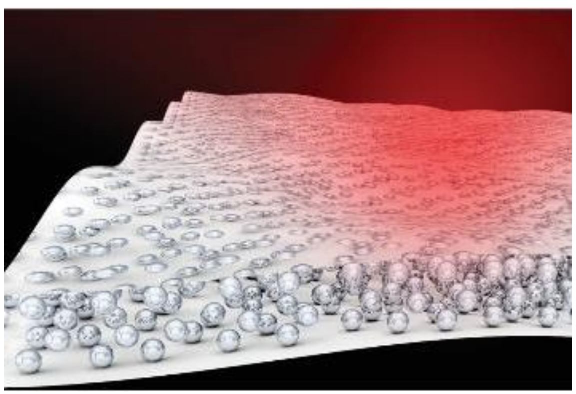


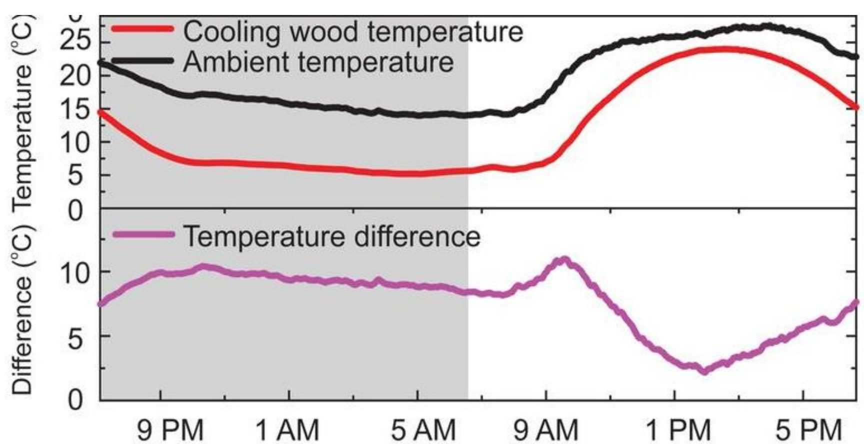


$R_{solar} = 0.97$

$\varepsilon = 0.7$

Ceramic in polymer





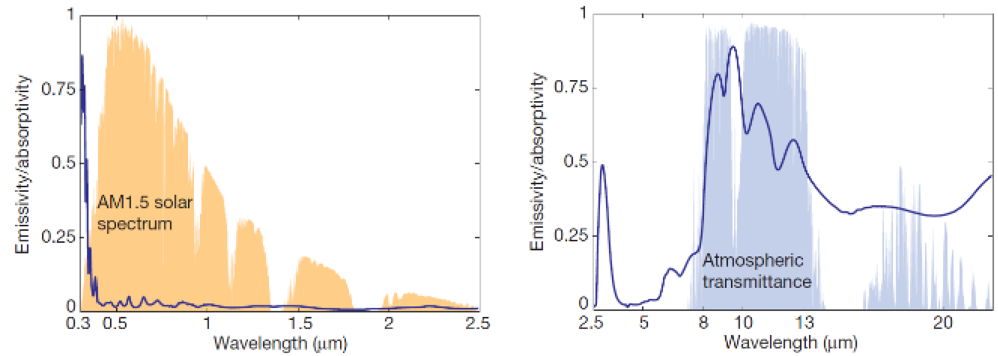
$R_{solar} = 0.96$

$\varepsilon = 0.93$

Shanhui fan group, *Nature* 515, 540 (2014)
Xiaobo Yin & Ronggui Yang, *Science* 355, 1062 (2017)

Radiative Cooling Panels

Columbia University



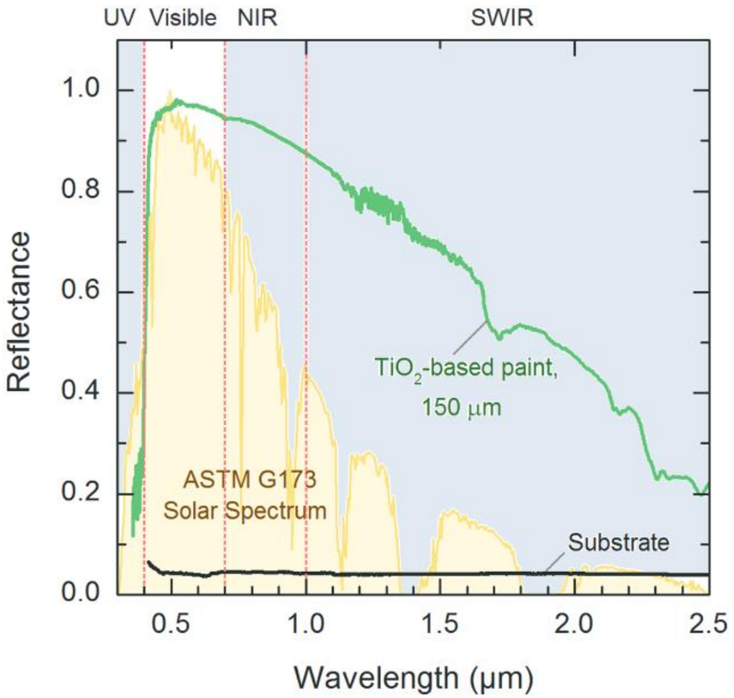
Raman et. al. (Nature, 2017)

- Good performance, but sophisticated.
- **Manufacture and use in advanced settings.**

Challenges: Cost, Rough Surface

Cooling Paints

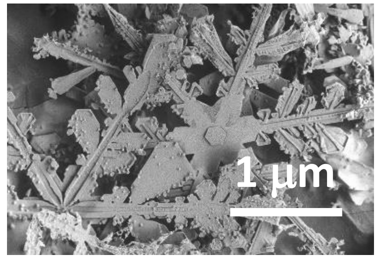
BRAND AND MODEL	SOLAR REFLECTANCE		THERMAL EMITTANC	
	INITIAL	3 YEAR	INITIAL	3 YEAR
APOC 256 X	0.94	0.75	0.88	0.89
R-Mer Coat 1531	0.93	Pending	0.90	Pending
AcryShield A590 High Reflectance White	0.92	0.87	0.87	0.88
AcryShield A179 High Reflectance White	0.92	0.81	0.88	0.85
APOC 256 FR White	0.91	0.81	0.89	0.88



- UV/SWIR absorptance.
- Pigment particles too small to reflect large solar wavelengths.
- R_{solar} < 0.94, typically 0.80-0.90
- Still heat up under sunlight.

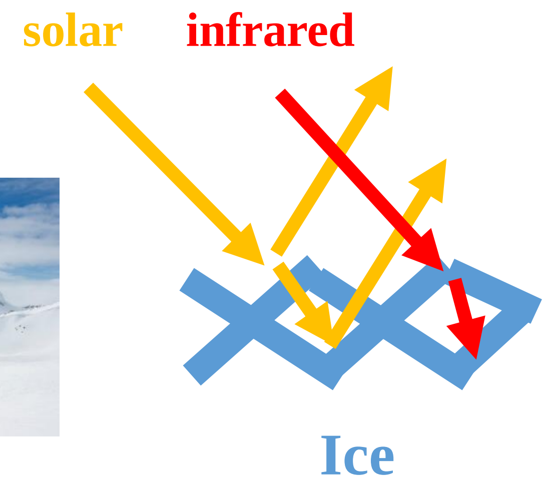
Learn from Nature

Ice: R ~ 0.02
ε ~ 0.96



Scattering due to mismatch in n (1.31 vs. 1)

Snow: R ~ 0.8-0.9
ε ~ 0.99



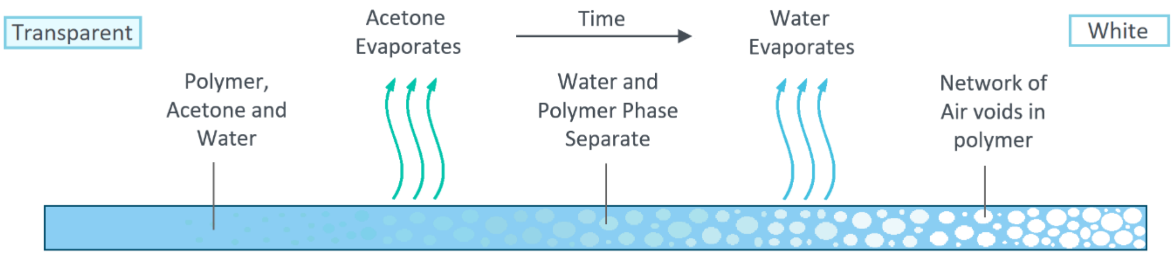
Broad, random nano/microstructures: efficient scattering for amplification

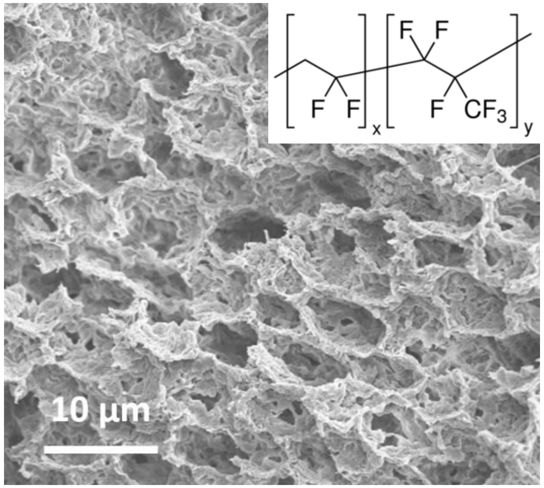
Solar spectrum (0.3-2.5 μm) : no intrinsic absorption

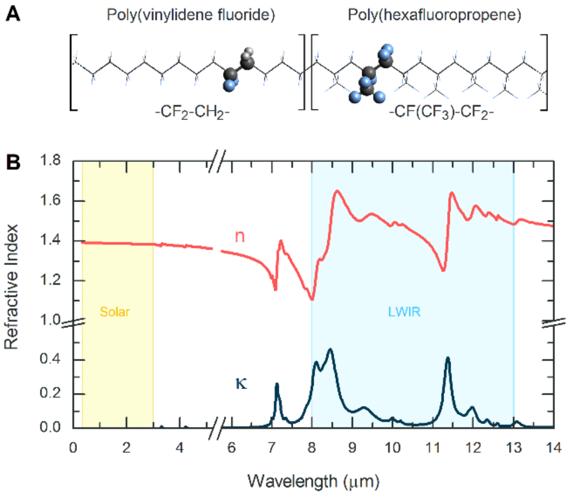
Infrared thermal radiation: strong intrinsic absorption (emissivity)

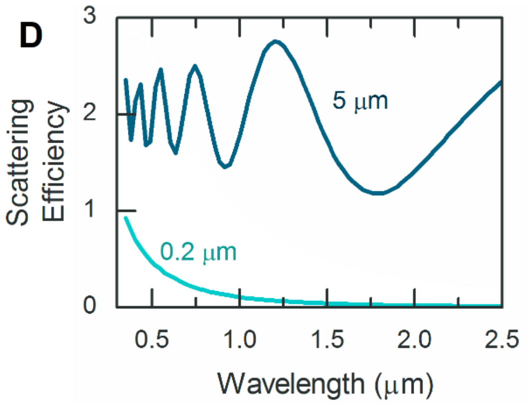
Radiative Cooling in Porous Polymer

Jyoti Mandal



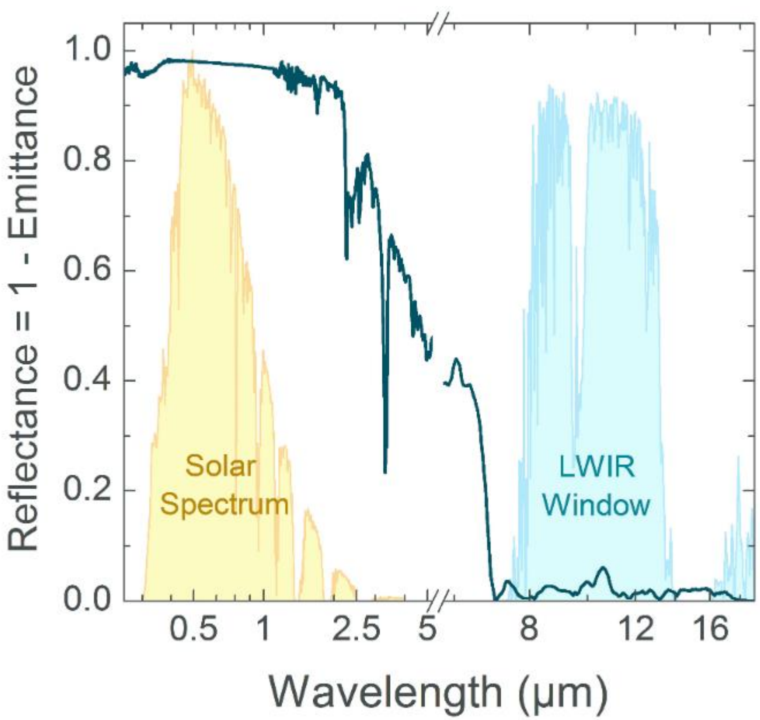


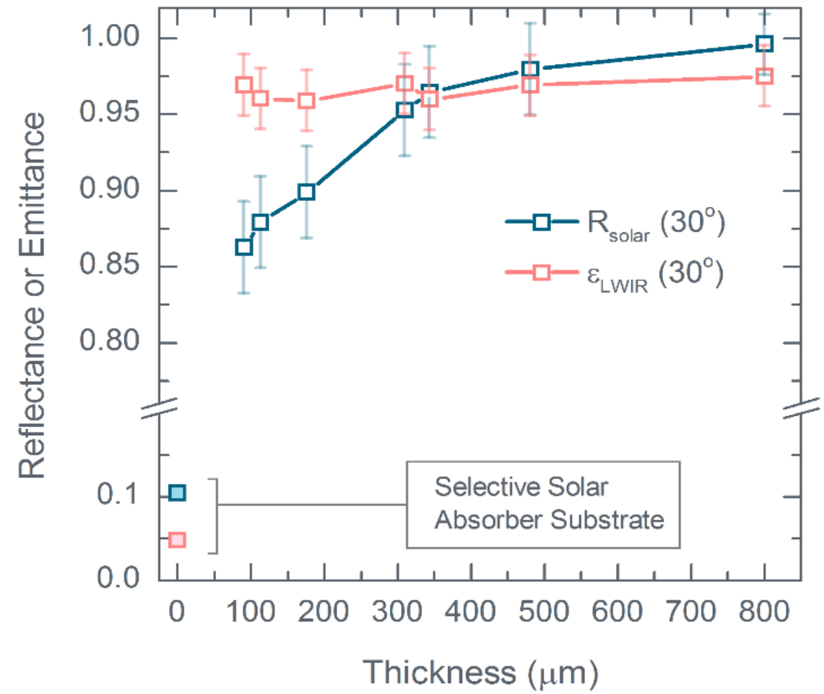




Jyotirmoy Mandal and Yuan Yang, *Science* 362, 315 (2018)

Radiative Cooling in Porous Polymer

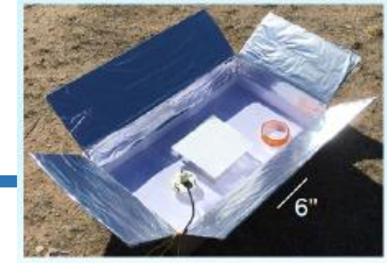


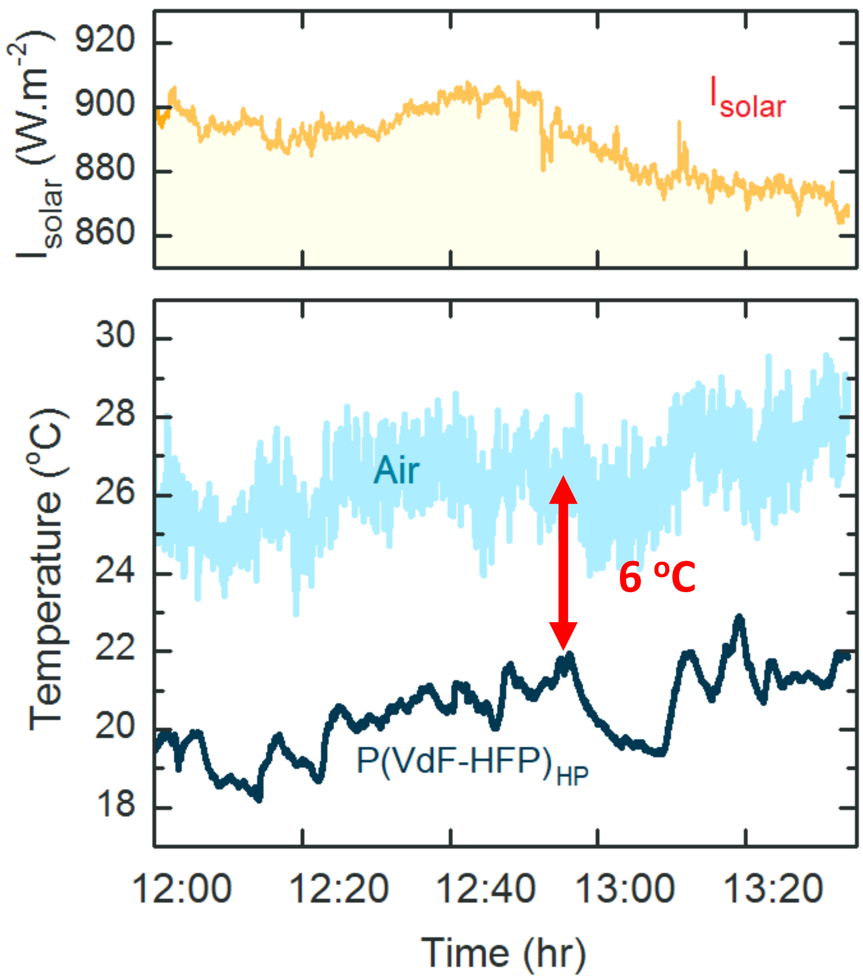


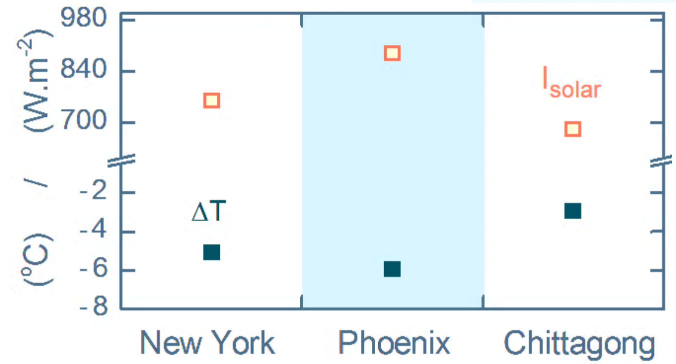
Porous PVdF-HFP: R ~ 0.96-0.996, ε ~ 0.97.

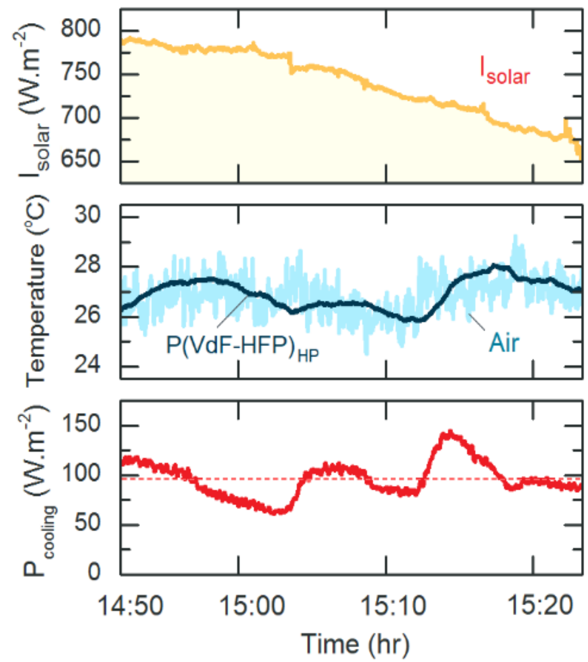
300 um thickness: ~$0.4/ft^2

Radiative Cooling in Porous Polymer









Application on Various Substrates

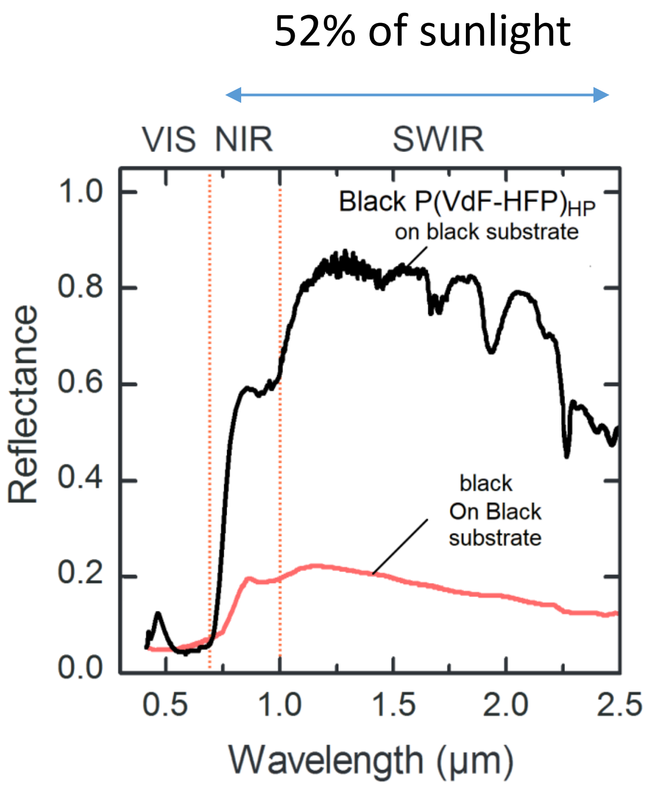
Applicable for most substrates with conformal coating.

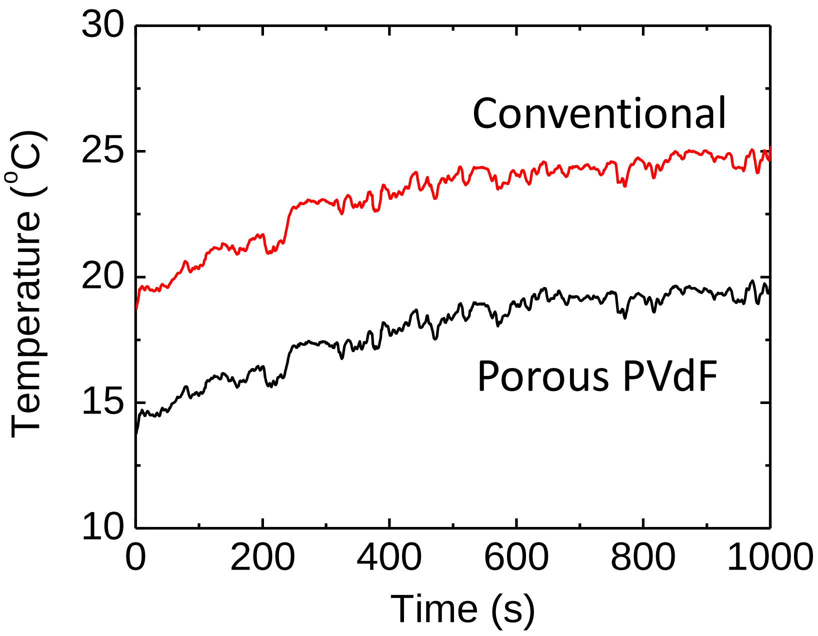
Degradation Tests

Test	Description	$\bar{R}_{solar}$ / $\bar{\epsilon}_{LWIR}$	
		Before	After
Accelerated thermal and wet aging tests	80˚C in air, for 14 days.	0.95/0.96	0.95/0.96
	80˚C in a chamber containing water at 100% relative humidity, for 14 days.	0.96/0.95	0.93/0.96
Monthlong exposure test under the sky in New York	Location: 40.8101˚ N, 73.9434˚ W. Date: 19 November – 18 December, 2017. Average Temperature ~5˚C, average relative humidity ~65%, occasional rain and light snow.	0.94/0.93	0.93/0.93
	Location: 40.8093˚ N, 73.9535˚ W. Date: 09 August – 17 August, 2018. Average Temperature ~25˚C, average relative humidity ~75%, occasional rain.	0.996/0.97	0.993/0.98

Third party test: (1000 hrs of QUV exposure): TSR from 0.96 to 0.89.

Application and Addition of Color



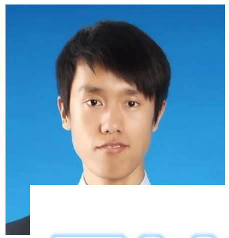


50% change in NIR/SWIR corresponds to 5-10 ºC cooling under wind.

Acknowledgement

Jyoti Mandal

Meijie Chen



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Master students

THANK YOU!

Questions?

Columbia University

PAS Center for Precision Assembly of Superstratic and Superatomic Solids Columbia-CCNY

Air Force Office of Scientific Research United States Air Force

Gotion